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(54) **Injection nozzle**

(57) An injection nozzle for use in delivering fuel to a combustion space includes a valve member in the form of a valve needle (18) which is slidable within a bore (11) and engageable with a seating (12A) to control fuel flow through an outlet opening (25A, 25B). The valve needle (18) includes first and second surfaces (27, 29) of substantially conical or frusto-conical form, and a circumferential groove (26) formed in the valve needle (18) intermediate the first and second surfaces (27, 29). The second surface (29) of the valve needle (18) is disposed eccentrically relative to the first surface (27), thereby providing the effect of a bushy spray upon relatively low amounts of valve needle lift away from the seating, whilst maintaining good spray symmetry throughout the remainder of the range of travel of the valve needle (18).

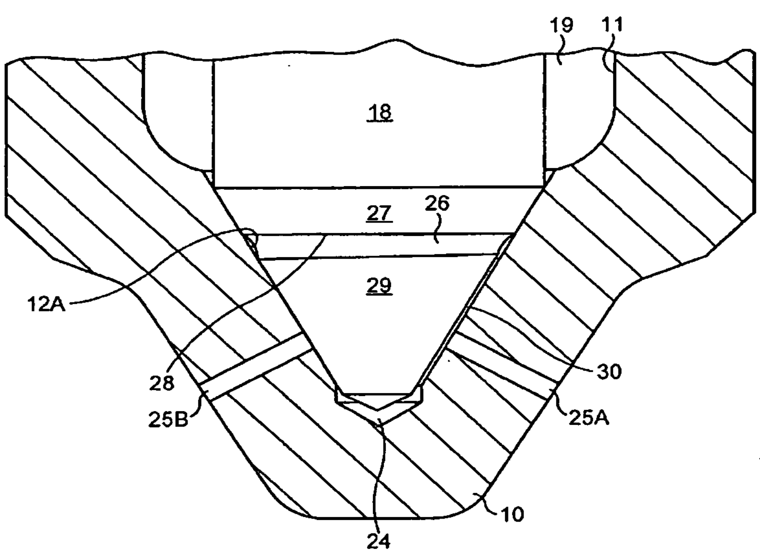

FIG. 3

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Description

[0001] The present invention relates to an injection nozzle for use in controlling fluid flow through an outlet and particularly, but not exclusively, to an injection nozzle for use in a fuel injector for delivering fuel to an internal combustion engine.

[0002] Such injection nozzles generally comprise a valve member which is slidable within a blind bore provided in a nozzle body. A region of the valve member proximal to the blind end of the bore is engageable with an annular valve seating, defined by a portion of the bore. The valve member is biased into engagement with the valve seating and is selectively movable away from the valve seating, thereby to control fuel delivery through a set of outlet openings provided in the nozzle body. In use, when the valve member is moved away from the valve seating, fuel within a delivery chamber defined by the bore and the outer surface of the valve member is able to flow past the valve seating and out through the outlet openings into an associated engine cylinder or other combustion space.

[0003] It is known from US 5,890,660 to provide an injection nozzle where the valve member defines first and second conical surfaces, the first conical surface being disposed upstream - in terms of the direction of flow of fuel - of the second conical surface. The first conical surface (i.e. that distal to the blind end of the bore) has a cone angle which is less than that of the valve seating, whereas the second conical surface (i.e. that proximal to the blind end of the bore) has a cone angle which is greater tan that of the valve seating. The valve member is provided with a circumferential groove, one edge of the groove forming with the downstream edge of the first conical surface a so-called "seating line" along which, in the closed position of the valve member, the valve member engages with the seating. The other edge of the groove corresponds to the upstream edge of the second conical surface.

[0004] Injection nozzles of this design provide a number of advantages. Over a period of time, deformation of the seating line will take place so that the seating line effectively becomes a zone or area. However, the presence of the groove prevents the effective seating line moving in the downstream direction so that the pressure which is required to lift the valve member from its seating (known in the art as the "nozzle opening pressure") is substantially unaffected. This enables the differential angle between the second conical surface and the seating to be made as small as possible, in the order of 2.5° or less. The junction of the two conical surfaces would lie on the seat line but because of the provision of the groove, there is no actual junction and the manufacturing difficulties of providing an accurate junction are avoided. In practice, the zone contact which develops means that the effective seating line moves in the upstream direction to provide compensation for spring relaxation.

[0005] In addition to the improved seat wear characteristics outlined above, the valve member geometry described in US 5,890,660 also provides a much improved spray symmetry and hole-to-hole spray form variation. The first differential angle (i.e. the angle between the first conical surface and the valve seating) and the groove combine to have an hydraulic centralising effect on the valve member. As a result, a more even flow to and within the outlet openings is achieved, resulting in an improved spray symmetry.

[0006] Engine trials indicate that significant smoke reduction is possible at some engine operating modes with such a nozzle, although this is at the expense of increased combustion noise. It is believed that the increased noise is due to the narrower, more uniform sprays produced by the nozzle. These sprays do not exhibit the varied forms normally associated with a VCO (valve covered orifice) nozzle, that is a mix of narrow and "bushy" sprays. As a result, more fuel is injected into the cylinder before conditions become appropriate for combustion to commence. This larger quantity of fuel ignites and burns rapidly and results in higher combustion noise.

[0007] It would be advantageous to provide an injection nozzle in which the initial spray form is more "bushy" but ensures good spray symmetry for most of the injection.

[0008] It is an aim of the present invention to address this problem.

[0009] According to one aspect of the present invention, therefore, there is provided an injection nozzle for use in delivering fuel to a combustion space, the injection nozzle comprising:

> a valve member, slidable within a bore and engageable with a seating to control fuel flow through a plurality of outlet openings;
>
> the valve member including first and second surfaces of substantially conical or frusto-conical form, and a circumferential groove formed in the valve member intermediate said first and second surfaces;

wherein the second surface is eccentrically disposed relative to the first surface.

[0010] The invention provides the advantage that, for relatively small amounts of valve needle lift away from the seating, an asymmetric flow regime is achieved, resulting in some of the sprays through the outlets having a more "bushy" effect than others. Sprays exhibiting a more "bushy" effect reach ignition conditions in the combustion space earlier than narrower sprays with less fuel having been injected by this time. The ignition process is therefore more gradual and less combustion noise is generated. As the valve member lifts further through its range of travel, the effect of the eccentricity has a less significant effect on the symmetry of the flow regime,

such that the spray form becomes substantially symmetric. Smoke reduction associated with the improved fuel/air mixing characteristics of the nozzle can therefore be maintained.

[0011] Preferably, the eccentricity of the second surface relative to the first surface is in the range 1 to 50 microns and is preferably greater than 5 microns. More preferably, the eccentricity of the second surface relative to the first surface is in the range of 5 to 25 microns, and still more preferably between 5 and 10 microns.

[0012] In a preferred embodiment, the injection nozzle is provided with means for biasing the valve member into engagement with the seating. Conveniently, the seating may be defined by the bore.

[0013] Advantageously, in a closed position of the valve member, there is a radial clearance between the second surface and the seating which radial clearance varies around the circumference of the second surface. Preferably, the difference in the maximum radial clearance between the second surface and the seating and the minimum radial clearance is in the range of 5 to 10 microns.

[0014] Preferably, a first edge of the groove defines a lower edge of the first surface and a second edge of the groove defines an upper edge of the second surface.

[0015] Conveniently, the first edge of the groove or the lower edge of the first surface defines a seating line along which, in a closed position of the valve member, the valve member engages with the seating.

[0016] Preferably, the seating is machined to frusto-conical form having a substantially constant cone angle. The first surface may have a cone angle which is less than that of the seating. Additionally, or alternatively, the second surface may have a cone angle which is greater than that of the seating.

[0017] Preferably, the included angle between the first surface and the seating and the included angle between the second surface and the seating are each in the range 0.1 to 5° and, more preferably, are each approximately 0.75°.

[0018] The present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a section through part of a known fuel injection nozzle;

Figure 2 is an enlarged view of part of the nozzle of Figure 1;

Figure 3 is a view, comparable with that of Figure 2, of a preferred form of nozzle according to the invention in a partially opened state; and,

Figure 4 shows the nozzle of Figure 3 in a substantially fully opened state.

[0019] In the following description, the terms "upper" and "lower", are used having regard to the orientation of the nozzle shown in the drawings. Likewise, the terms "upstream" and "downstream" are used with respect to the direction of fuel flow through the nozzle, from a fuel inlet line to outlets to the engine cylinder or other combustion space.

[0020] Referring to Figure 1, a known fuel injection nozzle comprises a nozzle body 10 of stepped cylindrical form having a blind bore 11 extending generally axially therein. A valve seating surface 12A, in the form of a generally frusto-conical restriction or narrowing, which is shown more clearly in Figure 2, is formed at the blind end of the bore and an enlargement 12, which communicates with a fuel inlet passage 13, is formed intermediate the ends of the bore. The fuel inlet passage 13 extends through an end portion 14 of the nozzle body 10 and through a wall portion of a nozzle holder 15 to a fuel inlet (not shown) which in use is connected to the outlet of a fuel injection pump.

[0021] The nozzle body 10 is secured to the nozzle holder 15 by means of a cap nut 17 and, in use, a narrower portion of the nozzle body 10 extends through a bore into a combustion space of an associated combustion engine.

[0022] A valve member in the form of a valve needle 18 is slidably mounted within the bore 11 and, along a portion of its length corresponding substantially to the region of the nozzle body 5 intermediate the enlarged portion 12 and the seating 12A, has a diameter which is less than that of the bore 11 thereby to define an annular space 19 through which fuel from the fuel inlet passage 13 can flow.

[0023] The valve needle 18 is provided with an extension 20 which extends with clearance through an aperture in the end portion 14 of the nozzle body 10. The free end of the extension 20 is engaged by a spring abutment 21 located at one end of a coiled compression spring 22, the other end of which bears against an abutment 23 of the nozzle holder 15. The spring 22 acts to maintain the valve needle 18 in the closed position and the chamber in which the spring is located is connected to a drain (not shown) through a passage 16.

[0024] As is more clearly shown in Figure 2, the seating 12A is of frusto-conical form and at its narrower end opens into a small recess or sac region 24, the purpose of which is to permit accurate grinding of the valve seating surface 12A. Two outlet openings 25 are disposed in the nozzle body 10 to allow fuel in and adjacent to the sac region 24 to flow out of the bore and into a combustion chamber of an associated engine. It will be appreciated however, that the number and position of the outlet openings 25 may be varied in dependence on the application for which the fuel injection nozzle is intended.

[0025] The lower end of the valve needle 18, adjacent or proximal to the blind end of the bore 11, includes a first, upper annular surface or region 27 of substantially frusto-conical form and a second, lower annular surface

or region 29 of generally conical form. The second region 29 defines the end or tip of the needle valve 18 and thus occupies a lower axial position along the axis of the valve member than the first region 27, the second region 29 therefore being disposed downstream of the first region 27.

[0026] The first region 27 has an outer surface defining a seating surface which is engageable with the valve seating surface 12A. The included angle between the valve seating surface 12A defined by the bore 11 and the seating surface defined by the first region 27 of the valve needle 18 (hereafter referred to as the first differential angle) is approximately 0.75° such that the cone angle of the seating surface is slightly less than that of the valve seating surface 12A. Typically, the differential angle is around 0.75° although satisfactory results may be obtained by the use of a differential angle of between approximately 0.1 and 5°

[0027] The included angle between the valve seating surface 12A defined by the bore and the surface of the second region 29 of the valve needle 18 (hereafter referred to as the second differential angle) is also 0.75° such that the cone angle of the latter is slightly greater than that of the valve seating surface. Once again, satisfactory results may be obtained by the use of a differential angle of between approximately 0.1 and 5°, although the value of 0.75° is preferred.

[0028] The needle valve 18 is provided with a circumferential groove 26 intermediate the first region 27 and the second region 29. An first, upper (or upstream) edge of the groove 26, is defined by a lower (or downstream) edge of the first region 27 while a second, lower (or downstream) edge of the groove 26 is defined by an upper (or upstream) edge of the second region 29.

[0029] The upstream edge of the groove 26 forms with the first region 27 a so-called "seating line" 28 and, in use, in the closed position of the valve needle 18, the latter engages with the valve seating surface 12A along the seating line 28. However, as shown in Figure 2, there is a clearance between the valve seating surface 12A and the needle valve 18, particularly in the region of the needle valve downstream of the seating line 28.

[0030] In operation, when fuel under pressure is supplied to the inlet 13, fuel pressure acts on the area of the valve needle 18 upstream of the seating line 28 and an upward force is therefore generated on the valve needle 18 which opposes the downward force exerted by the spring 22. When the force due to the fuel pressure exceeds the combined force of the spring 22 and any force due to fuel pressure acting on a back end of the valve needle 18 remote from the outlet opening 25, the valve needle 18 moves to an open position and fuel is then able to flow past the valve seating surface 12A and through the outlet openings 25 in the bore 11.

[0031] Referring now to Figure 3, this illustrates part of a preferred form of injection nozzle according to the invention in a view comparable to that of Figure 2. Although not wholly clear from the drawing, the geometry of the valve needle 18 of Figure 3 is substantially identical to that of Figure 2. Thus, the valve needle 18 includes first and second regions 27, 29 and an intermediate groove 26. The first and second differential angles are in the range of 0.1 to 5°, and are preferably both 0.75°.

[0032] However, importantly, in the injection nozzle of Figure 3, the second region 29 of the needle valve 18 is disposed eccentrically (i.e. axially offset) relative to the first region 27 such that, in the closed position of the valve needle, a radial clearance 30 is provided between the surface of the second region 29 and the outlet openings 25A, 25B which varies around the circumference of the second region 29. Thus, the second region has a larger clearance with some outlet openings (e.g. opening 25A in the drawing) than with others (e.g. opening 25B). In the preferred embodiment, the eccentricity of the second region 29 relative to the first region 27 (i.e. the difference in the maximum radial clearance between the second region 29 and the outlet openings and the minimum radial clearance) is in the range of 1 to 100 microns and, more preferably, in the range of 5 to 10 microns.

[0033] In operation, when the nozzle opening pressure (the pressure which is required to lift the valve needle 18 from its seating) exceeds the force of the spring 22, the valve needle 18 moves to the open position, as described above with reference to Figure 2. Fuel is then able to flow past the valve seating surface 12A and through the outlet openings 25A, 25B. During the initial lifting movement of the valve needle 18, the first region 29 and the groove 26 act to keep the first region 29 concentric with the nozzle body 10.

[0034] As the valve member begins to lift away from the seating (i.e. for relatively small amounts of lift), the eccentricity of the second region 29 relative to the first region 27 has a significant effect on the symmetry of the fuel flow in the tip 30, 24 of the injection nozzle. An asymmetric flow regime is therefore provided, with more fuel flowing through outlet opening 25A than through outlet opening 25B. In practice, this asymmetric flow regime results in some of the sprays having a more "bushy" effect than others. Moreover, since the eccentricity of the second region 29 relative to the first region 27 is small, the asymmetric fuel flow is a highly controlled effect.

[0035] It will be appreciated that those sprays exhibiting a more "bushy" effect reach ignition conditions earlier than the narrower sprays with less fuel having been injected by this time. Hence, the ignition process is more gradual and less combustion noise is generated.

[0036] As the valve needle 18 lifts further through its range of travel, as shown in Figure 4, the effect of the eccentricity between the second region 29 and the first region 27 has a less significant effect on the symmetry of the flow regime set up in the tip of the injection nozzle (i.e. through the clearance 30 and within the sac region 24) such that the spray form becomes substantially symmetric. In this manner, at or around maximum lift of the

valve needle 18, the smoke reduction associated with the improved fuel/air mixing characteristics exhibited by the nozzle of Figure 2 can be maintained.

[0037] It will be appreciated that the present invention provides a simple and effective improvement over existing nozzles and provides a particular advantage where improved noise reduction is required in addition to improved smoke reduction.

[0038] It will be further appreciated that the differential angle values and the eccentricity values disclosed above are not intended to be limiting and may take different values to those described. More particularly, the first and second differential angles need not be identical and may take any suitable range, although the preferred range is between 0.1 and 5°, and more preferably between 0.5 and 1°. The eccentricity of the second region 29 relative to the first region 27 (i.e. the perpendicular offset of the central axis of the second region 29 relative to that of the first region 27), is preferably between 1 and 25 microns and, more preferably, is between 5 and 10 microns. Advantageously, however, the eccentricity is arranged such that the effect for a relatively small extent of valve needle lift is substantially less than the effect for a relatively large extent of lift.

[0039] The injection nozzle of the present invention may be incorporated in a unit/pump injector or in a fuel injector arranged to be supplied with fuel from a common rail fuel system. It will be appreciated that movement of the valve needle 18 within the blind bore 11 to open and close the outlet openings 25A, 25B may be controlled in any appropriate manner, for example by means of a piezoelectric or electromagnetic actuator arrangement, and that the fuel injector may be of the single or multi-stage lift type, the nozzle body 10 of the injector injection nozzle being provided with an appropriate number of outlet openings for fuel accordingly.

[0040] In embodiments for which movement of the valve needle 18 is controlled by means of an actuator arrangement, it will be familiar to those skilled in the art that valve needle movement may be effected, for example, by providing an actuation force directly to the valve needle 18, or through a hydraulic amplifier arrangement or though a needle control valve for controlling fuel pressure acting on the back end of the valve needle 18 remote from the outlet openings 25A, 25B.

[0041] It will also be appreciated that the injection nozzle of the present invention may be used in controlling the delivery of any fluid, and is not limited to use in injecting fuel.

Claims

1. An injection nozzle for use in delivering fuel to a combustion space, the injection nozzle comprising:

    a valve member (18), slidable within a bore (11) and engageable with a seating (12A) to control fuel flow through a plurality of outlet openings (25A, 25B);

    wherein the valve member (18) includes first and second surfaces (27, 29) of substantially conical or frusto-conical form, and a circumferential groove (26) formed in the valve member (18) intermediate the first and second surfaces (27, 29);
    characterised in that said second surface (29) is disposed eccentrically relative to the first surface (27).

2. An injection nozzle as claimed in claim 1, including means for biasing the valve member (18) into engagement with the seating (12A).

3. An injection nozzle as claimed in claim 1 or claim 2, wherein the eccentricity of the second surface (29) relative to the first surface (27) is in the range 1 to 25 microns.

4. An injection nozzle as claimed in any one of claims 1 to 3, wherein the eccentricity of the second surface (29) relative to the first surface is greater than 5 microns.

5. An injection nozzle as claimed in any one of claims 1 to 4, wherein the eccentricity of the second surface (29) relative to the first surface (27) is in the range of 5 to 10 microns.

6. An injection nozzle as claimed in any one of claims 1 to 5, wherein in a closed position of the valve member (18), there is a radial clearance between the second surface (29) and the seating (12A) which radial clearance varies around the circumference of the second surface (29).

7. An injection nozzle as claimed in claim 6, wherein the difference in the maximum radial clearance between the second surface (29) and the seating (12A) and the minimum radial clearance is greater than 5 microns.

8. An injection nozzle as claimed in claim 7, wherein the difference in the maximum radial clearance between the second surface (29) and the seating (12A) and the minimum radial clearance is in the range of 5 to 10 microns.

9. An injection nozzle as claimed in any one of claims 1 to 8, wherein a first edge of the groove (26) defines a lower edge of the first surface (27) and a second edge of the groove (26) defines an upper edge of the second surface (26).

10. An injection nozzle as claimed in claim 9, wherein the first edge of the groove (26) or the lower edge

of the first surface (27) defines a seating line (28) along which, in a closed position of the valve member (18), the valve member (18) engages with the seating (12A).

11. An injection nozzle as claimed in any one of claims 1 to 10, wherein the seating (12A) is machined to conical or frusto-conical form having a substantially constant cone angle.

12. An injection nozzle as claimed in claim 11, wherein the first surface (27) has a cone angle which is less than that of the seating (12A).

13. An injection nozzle as claimed in claim 11 or claim 12, wherein the second surface (29) has a cone angle which is greater than or substantially equal to that of the seating (12A).

14. An injection nozzle as claimed in any one of claims 1 to 13, wherein the first surface (27) and the seating (12A) defined by the bore (11) define a first differential angle, wherein said first differential angle is between 0.1 and 5°.

15. An injection nozzle as claimed in any one of claims 1 to 14, wherein the second surface (29) and the seating (12A) defined by the bore (11) define a second differential angle, wherein said differential angle is between 0.1 and 5°.

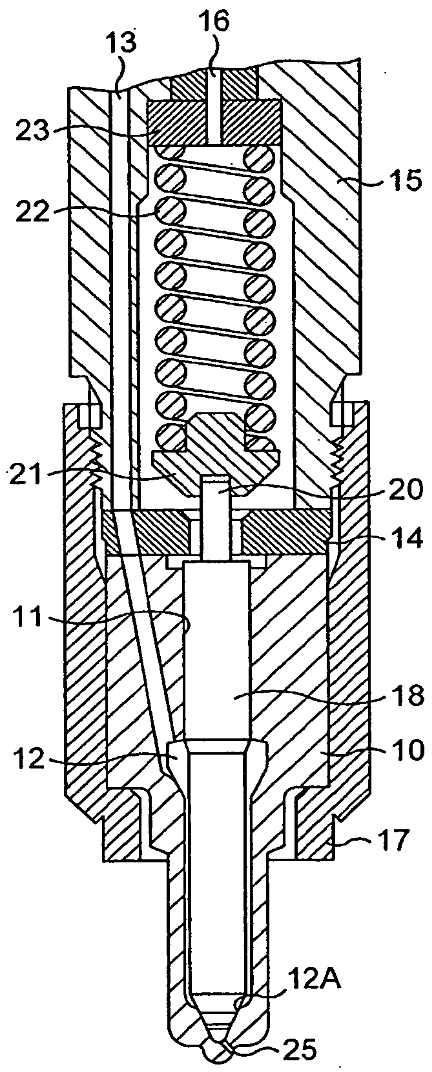

FIG. 1
PRIOR ART

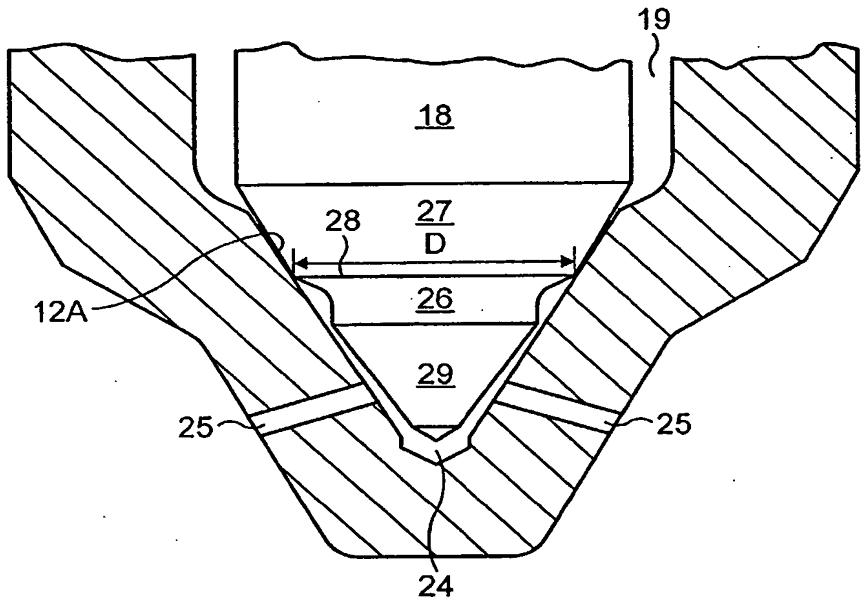

FIG. 2
PRIOR ART

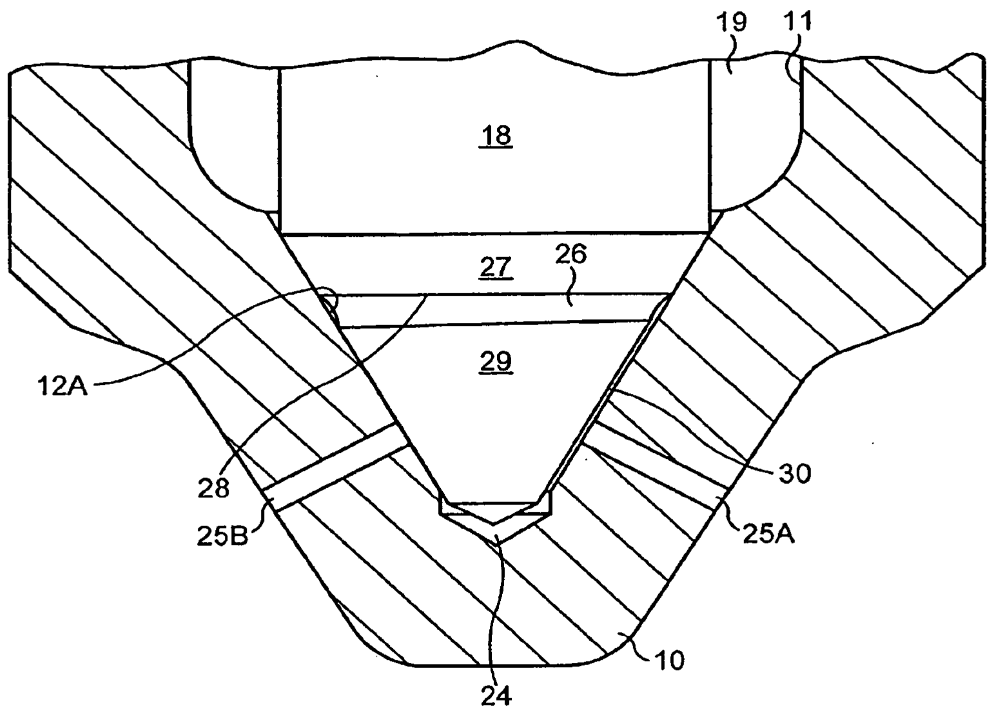
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FIG. 3

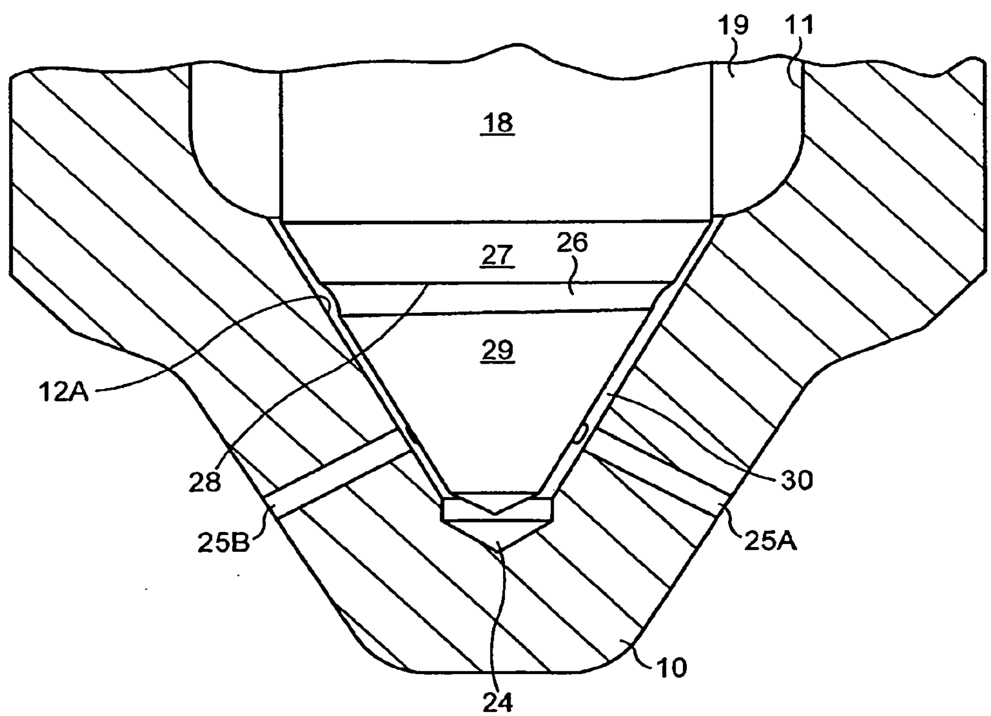
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FIG. 4